Snowmass 2021 restart: Dark matter at colliders (EF10)

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Liantao Wang (University of Chicago)
Energy Frontier Topical Group convenors (EF10)

2021/09/02 - TG conveners meeting

EF10 goals recap: testing the WIMP paradigm

1. **Electroweak multiplets [meeting 04/06/20, 02/07/20]**
   - Electroweak multiplet: higgsino/wino(minimal DM). Mediator: W/Z/h.
   - Target: TeV(and above)-scale DM masses, motivated by relic density

Common benchmarks with EF08/CF

2. **Simplified mediator models [meeting 18/06/20]**
   - S-channel and t-channel mediators.
   - Well established benchmarks for LHC, simple benchmarks for comparisons
   - Main target: DM masses < ½ mediator mass.

Common benchmarks with EF09/RF06/CF

3. **Higgs portal [upcoming meeting]**
   - Well motivated coupling between SM to the dark world
   - Main target: DM masses < ½ Higgs mass.

Common benchmark with Higgs EFs

EF10 goals recap: beyond WIMPs

[joint EF09-10/RF05/AF06 meeting 16-17/07]

1. (Very) different DM masses and couplings with respect to the WIMP
   a. Strongly interacting DM, light DM (< GeV)
      i. E.g. dark QCD benchmarks *LOI*

Common benchmarks in discussion with EF09/RF05, also to be discussed with CF

2. Different portals with respect to LHC simplified models:
   a. dark photon and generic dark scalar/pseudoscalar (including rare decays)
      i. Develop connections between these portals and DM simplified models
      See this talk by N. Toro at the "LLP preparatory meeting" (EF8-10/RF05/AF06)
      ii. Understand how to present them coherently - see this talk by N. Toro at EF10 meeting

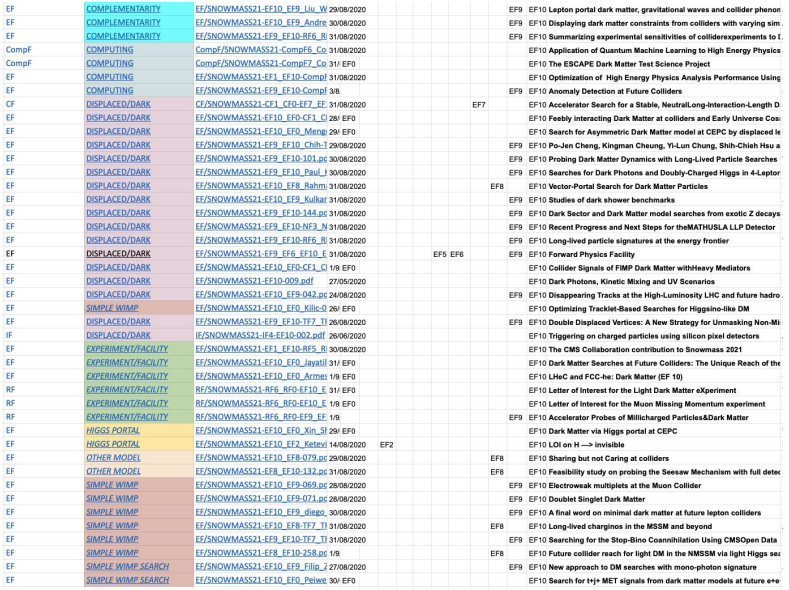
Before the break: work on LOIs

44 LOIs so far [EF10 LOIs: links and titles]

Mostly cross-listed with EF09/CF

Roughly grouped by topics:

- WIMP (9) *Covered in September 10 biweekly meeting.*
- Alternative models (2) *Covered in September 10 biweekly meeting.*
- Displaced, dark sector (17)
- Higgs portal (2)
- Directly related to a facility. (5) *Covered in Sept 23rd meeting*
- Computing. (4)
- Complementarity between different probes (4)
  Covered in Sept 23rd meeting



EF	COMPLEMENTARITY	EF/SNOWMASS21-EF10_EF9_Liu_W	29/08/2020					EF9	EF10 Lepton portal dark matter, gravitational waves and collider phenon
EF	COMPLEMENTARITY	EF/SNOWMASS21-EF10_EF9_Andre	30/08/2020					EF9	EF10 Displaying dark matter constraints from colliders with varying sim
EF	COMPLEMENTARITY	EF/SNOWMASS21-EF9_EF10-RF6_R	31/08/2020					EF9	EF10 Summarizing experimental sensitivities of colliderexperiments to D
CompF	COMPUTING	CompF/SNOWMASS21-CompF6_Co	31/08/2020						EF10 Application of Quantum Machine Learning to High Energy Physics
CompF	COMPUTING	CompF/SNOWMASS21-CompF7_Co	31/ EF0						EF10 The ESCAPE Dark Matter Test Science Project
EF	COMPUTING	EF/SNOWMASS21-EF1_EF10-CompF	31/08/2020						EF10 Optimization of High Energy Physics Analysis Performance Using
EF	COMPUTING	EF/SNOWMASS21-EF9_EF10-CompF	3/8					EF9	EF10 Anomaly Detection at Future Colliders
CF	DISPLACED/DARK	CF/SNOWMASS21-CF1_CF0-EF7_EF	31/08/2020				EF7		EF10 Accelerator Search for a Stable, NeutralLong-Interaction-Length D
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF0-CF1_Cl	28/ EF0						EF10 Feebly interacting Dark Matter at colliders and Early Universe Cos
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF0_Meng	29/ EF0						EF10 Search for Asymmetric Dark Matter model at CEPC by displaced le
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10_Chih-T	29/08/2020					EF9	EF10 Po-Jen Cheng, Kingman Cheung, Yi-Lun Chung, Shih-Chieh Hsu a
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10-101.pc	30/08/2020					EF9	EF10 Probing Dark Matter Dynamics with Long-Lived Particle Searches
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10_Paul_J	30/08/2020					EF9	EF10 Searches for Dark Photons and Doubly-Charged Higgs in 4-Leptor
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF8_Rahm	31/08/2020				EF8		EF10 Vector-Portal Search for Dark Matter Particles
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF9_Kulkar	31/08/2020					EF9	EF10 Studies of dark shower benchmarks
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10-144.pc	31/08/2020					EF9	EF10 Dark Sector and Dark Matter model searches from exotic Z decays
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10-NF3_N	31/08/2020					EF9	EF10 Recent Progress and Next Steps for theMATHUSLA LLP Detector
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10-RF6_R	31/08/2020					EF9	EF10 Long-lived particle signatures at the energy frontier
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF6_EF10_E	31/08/2020		EF5	EF6		EF9	EF10 Forward Physics Facility
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF0-CF1_Cl	1/9 EF0						EF10 Collider Signals of FIMP Dark Matter withHeavy Mediators
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10-009.pdf	27/05/2020						EF10 Dark Photons, Kinetic Mixing and UV Scenarios
EF	DISPLACED/DARK	EF/SNOWMASS21-EF10_EF9-042.pc	24/08/2020					EF9	EF10 Disappearing Tracks at the High-Luminosity LHC and future hadro
EF	SIMPLE WIMP	EF/SNOWMASS21-EF10_EF0_Kilic-0	26/ EF0						EF10 Optimizing Tracklet-Based Searches for Higgsino-like DM
EF	DISPLACED/DARK	EF/SNOWMASS21-EF9_EF10-TF7_TI	26/08/2020					EF9	EF10 Double Displaced Vertices: A New Strategy for Unmasking Non-Mi
IF	DISPLACED/DARK	IF/SNOWMASS21-IF4-EF10-002.pdf	26/06/2020						EF10 Triggering on charged particles using silicon pixel detectors
EF	EXPERIMENT/FACILITY	EF/SNOWMASS21-EF1_EF10-RF5_R	30/08/2020						EF10 The CMS Collaboration contribution to Snowmass 2021
EF	EXPERIMENT/FACILITY	EF/SNOWMASS21-EF10_EF0_Jayatil	31/ EF0						EF10 Dark Matter Searches at Future Colliders: The Unique Reach of the
EF	EXPERIMENT/FACILITY	EF/SNOWMASS21-EF10_EF0_Armes	1/9 EF0						EF10 LHeC and FCC-he: Dark Matter (EF 10)
RF	EXPERIMENT/FACILITY	RF/SNOWMASS21-RF6_RF0-EF10_E	31/ EF0						EF10 Letter of Interest for the Light Dark Matter eXperiment
RF	EXPERIMENT/FACILITY	RF/SNOWMASS21-RF6_RF0-EF10_E	1/9 EF0						EF10 Letter of Interest for the Muon Missing Momentum experiment
RF	EXPERIMENT/FACILITY	RF/SNOWMASS21-RF6_RF0-EF9_EF	1/9					EF9	EF10 Accelerator Probes of Millicharged Particles&Dark Matter
EF	HIGGS PORTAL	EF/SNOWMASS21-EF10_EF0_Xin_SI	29/ EF0						EF10 Dark Matter via Higgs portal at CEPC
EF	HIGGS PORTAL	EF/SNOWMASS21-EF10_EF2_Ketevi	14/08/2020	EF2					EF10 LOI on H --> invisible
EF	OTHER MODEL	EF/SNOWMASS21-EF10_EF8-079.pc	29/08/2020				EF8		EF10 Sharing but not Caring at colliders
EF	OTHER MODEL	EF/SNOWMASS21-EF8_EF10-132.pc	31/08/2020				EF8		EF10 Feasibility study on probing the Seesaw Mechanism with full detec
EF	SIMPLE WIMP	EF/SNOWMASS21-EF10_EF9-069.pc	28/08/2020					EF9	EF10 Electroweak multiplets at the Muon Collider
EF	SIMPLE WIMP	EF/SNOWMASS21-EF10_EF9-071.pc	28/08/2020					EF9	EF10 Doublet Singlet Dark Matter
EF	SIMPLE WIMP	EF/SNOWMASS21-EF10_EF9_diego	30/08/2020					EF9	EF10 A final word on minimal dark matter at future lepton colliders
EF	SIMPLE WIMP	EF/SNOWMASS21-EF10_EF8-TF7_TI	31/08/2020				EF8		EF10 Long-lived charginos in the MSSM and beyond
EF	SIMPLE WIMP	EF/SNOWMASS21-EF9_EF10-TF7_TI	31/08/2020					EF9	EF10 Searching for the Stop-Bino Coannihilation Using CMSOpen Data
EF	SIMPLE WIMP	EF/SNOWMASS21-EF8_EF10-258.pc	1/9				EF8		EF10 Future collider reach for light DM in the NMSSM via light Higgs se
EF	SIMPLE WIMP SEARCH	EF/SNOWMASS21-EF10_EF9_Filip_2	27/08/2020					EF9	EF10 New approach to DM searches with mono-photon signature
EF	SIMPLE WIMP SEARCH	EF/SNOWMASS21-EF10_EF0_Peiwe	30/ EF0						EF10 Search for t+j+ MET signals from dark matter models at future e+e

We answered ~all LOIs individually

- Useful to build a discourse with the proponents, and to match-make with SEC members who contacted us

Recordings and notes available in the spreadsheet

What happened during the break?

Our feeling: people (us included) really took a Snowmass break
→ mostly worked on other things (still relevant for Snowmass)

We did not organize a conversation meeting - mostly because main EF10 contributors were busy/left

Parallel efforts were encouraged and followed, naming the most relevant/active:

- Snowmass *Dark Showers group* (joint with EF09) - Suchita Kulkarni [th], Marie-Helene Genest [exp]
  - Had a number of meetings on new publications / benchmark discussions (~ every 3 weeks)
  - Organized a tutorial/workshop with experts during the Long Lived Particles Community Workshop
  - Talk by Suchita Kulkarni today
- WIMPs at muon colliders
  - There have been several studies on the search for WIMP dark matter (focusing on the so called Minimal Dark Matter scenario) at muon collider (with various energy and luminosity options), as well as a few more on-going work.
  - While it may not be as complete as the study for the 100 TeV pp collider for the briefing book, a set of basic results are available now to paint a big picture on this topic.
  - Talks by M. Costa and J. Zurita today
- WIMPs and lighter DM at hadron/lepton colliders → see also next slide
  - Some of our main contributors graduated, some are back as PhD students starting in September, some are new
  - One of the postdoc leaders of whitepaper also moving on to new jobs (!colliders) but want to keep contributing once Snowmass restarts
  - Talks by A. Albert today
- New Wino/Higgsino studies with monojet signature ongoing - Andie Wall & Elliott Lipeles

Tentative plan for the future

- Resuming monthly meetings
  - Next meetings: **September 22, Oct 27, and Nov 17**
- Discussion ongoing for a joint EF-8/9/10 workshop early 2022.
- Don't hesitate to bring updates to our attention
  (even though we will ask for contributions)
  - We can only include in final whitepapers what we know about!
- Discussions for DM complementarity plots also expected to resume once Cosmic Frontier restarts (September onwards)

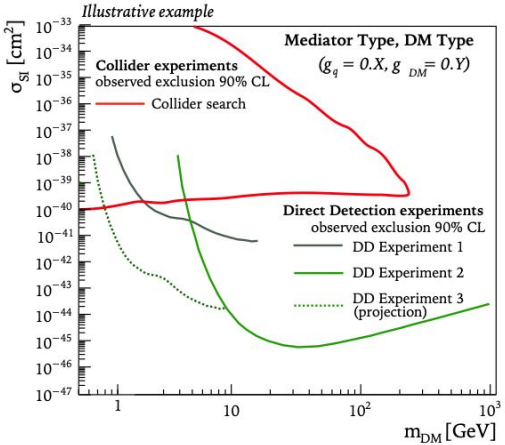
Bonus slides

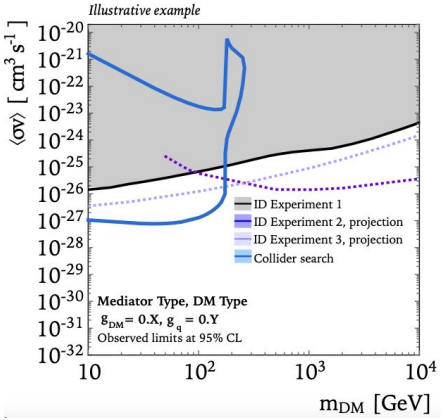
Caterina Doglioni (Lund University)
Liantao Wang (University of Chicago)
Energy Frontier Topical Group convenors (EF10)

WIMPs and lighter DM at future colliders

Work done within EF10 towards whitepaper was written up in Boyu Gao's thesis (Undergraduate @ OSU → Graduate school @ Duke). Link to thesis: https://kb.osu.edu/handle/1811/92563

Currently recruited a few new members (with the help of SEC Matt LeBlanc and Grace Cummings) to compile list of DM @ collider curves for summary plots and update European Strategy ones if needed:

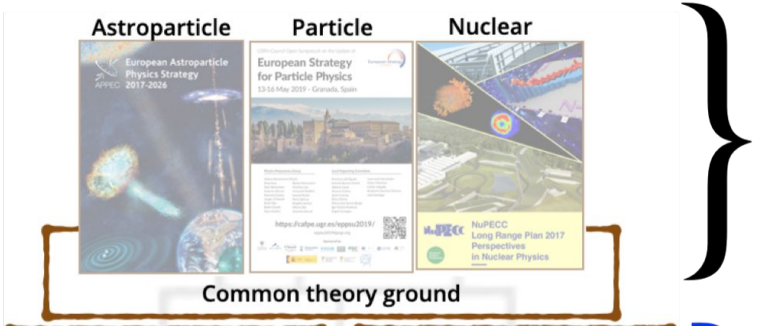




Work also will include the planned DMWG whitepaper (and discussion with other Frontiers) on lowering the couplings for the simplified models used by the LHC → see discussion on Tuesday

Bonus slide: two other activities adjacent to EF10

scientific outcome:
searches & interpretation



foundations:
(open) data & software tools

JENAA
Joint ECFA-NuPECC-APPEC Activities

Initiative for Dark Matter in Europe and Beyond (iDMEu)

Online platform / series of meetings to discuss dark matter synergies across all experiment & theory fields, endorsed by European particle / astroparticle and nuclear physics communities

Link to JENAA Expressions of Interest: http://nupecc.org/jenaa/?display=eois

Link to kick-off meeting w/recordings: https://indico.cern.ch/e/iDMEuKickOff

Can work in synergy with Snowmass / advertise EF10+CF+IF discussions to European community (current priority: completing website)

Dark Matter Test Science Project

5 postdocs working in European institutes on reproducible and sustainable dark matter analysis (colliders, DD, ID) in the European Open Science Cloud

https://projectescape.eu/dark-matter-test-science-project

Summary in slides: https://indico.cern.ch/event/955391/contributions/4075802/

Will share/use Snowmass EF10 machinery for producing summary plots